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(54) Method of fabricating a capacitive pressure transducer

Verfahren zur Herstellung eines kapazitiven Druckwandlers

Procédé de fabrication d'un appareil transducteur de pression capacitif

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Description**Background of the Invention**

The invention relates generally to pressure sensors and more particularly to pressure responsive variable parallel plate capacitive transducers. Such transducers are shown and described, for example, in U.S. Patent No. 4,716,492, assigned to the assignee of the present invention. A capacitive transducer is shown in the patent having a thin ceramic diaphragm mounted in closely spaced, sealed, overlying relation on a ceramic base, with metal coatings deposited on respective opposing surfaces of the diaphragm and the base to serve as capacitor plates arranged in predetermined closely spaced relation to each other to form a capacitor. Transducer terminals connected to the capacitor plates are arranged at an opposite surface of the transducer base and a signal conditioning electrical circuit connected to the transducer terminals is mounted on the transducer. A cup-shaped connector body of electrical insulating material is fitted over the electrical circuit and is secured to the transducer by a housing sleeve which has a port for exposing the transducer diaphragm to an applied pressure. The diaphragm is movable in response to variations in pressure applied to the diaphragm to vary the capacitance of the capacitor and the electrical circuit provides an electrical output signal corresponding to the applied pressure.

In order to maximize the economies of mass production to lower the transducer cost and thereby make such transducers economically feasible for a wide number of applications, including many previously served by low cost mechanical transducers, a standard size package is selected small enough to be received in a large number of applications yet large enough to provide a reliable signal. The size of the package determines the maximum size of the capacitor plates which, along with the gap between the plates, determines the capacitance signal. This results in limiting the size of the capacitor plates to a smaller size than would be ideal for many applications and relying on the electrical circuit to properly condition the signal. The circuit, on the other hand, requires a minimum level of capacitance for it to be able to effectively condition the output signal and this in turn affects the distance or gap required between the capacitor plates to produce the minimum capacitance level. In transducers of the type disclosed in U.S. Patent No. 4,716,492 distances between the plates are in the order of 10-17 micrometres (microns).

One approach described in the above patent to provide this selected gap employs a cup-shaped member having a relatively rigid rim secured to a base substrate placing a bottom of the cup in selected, spaced, overlying relation to a capacitor plate on the base substrate. An electrically conductive layer is disposed on the inner surface of the cup bottom to provide the second capacitor plate with the bottom being resiliently flexible to

serve as a diaphragm to move the second plate toward and away from the first capacitor plate in response to variations in fluid pressure applied to the outer surface of the bottom of the cup. The configuration of the cup-shaped member, however, is not conducive to low cost manufacturing techniques. Due, in part, to the small sizes involved it is very difficult to obtain consistent flat surfaces on the cup bottoms which are parallel to the substrate surface. Slight variations from device to device

- 5 cause changes in capacitance signals produced by the transducers which frequently fall outside the window of values acceptable by the signal conditioning circuitry.
- 10 Another approach described in the above patent employs a flat diaphragm element secured to the base substrate in selectively spaced relation thereto by disposing a spacing and securing medium such as a mixture of glass frit including a plurality of balls of glass of selected diameter between the flat diaphragm and the substrate at the periphery of the diaphragm. The glass frit is selected to be fusible at a first temperature at which the balls remain unfused and the mixture is then heated to the fusing temperature of the frit to secure the diaphragm to the substrate at a spacing from the substrate determined by the diameter of the balls. The provision of flat surfaces which extend over the entire diaphragm as well as the base substrate is very conducive to consistent, reproducible results from device to device; however, the flat surfaces generally require grinding to ensure that the surfaces are parallel to one another. Further, the use of the glass material to both space and secure the diaphragm to the base results in undesirable yield losses due to various factors such as unevenness sometimes occurring due to imperfections in the grinding process, variations in the compressive force used to clamp the diaphragms to the base when the device is fired to fuse the glass and other process variables such as the specific temperature profile of the firing and the specific glass composition employed.

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In U.S. Patent No. 5,044,202, assigned to the assignee of the instant invention, a curved recess is formed in the base over which a flat, flexible diaphragm is disposed. The spacing between capacitor plates deposited on the diaphragm and a central portion of the recess is determined by the curvature of the recess. Sealant material such as glass is disposed on the outer marginal portion of the curved surface of the recess. While this structure provides a reliable, accurate sensor it requires an extra grinding operation to form the recess which adds to the expense of the device.

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In EP-A-0 473 109, a pressure transducer is described which is made from two elongated unsintered ceramic sheets bonded together with a gap between them at one end. Conductive patterns are formed on the facing surfaces of the sheets to act as the electrodes of a capacitor the spacing of which varies with change in pressure applied to the transducer. In one sample described a carbon spacer is placed between the unsintered sheets which are then bonded together by an ad-

hesive or thermal compression. After bonding the components are heated to remove the resin binder of the sheets and to burn away the carbon spacer. Finally the ceramic material is sintered at high temperature to form an integral assembly.

SUMMARY OF THE INVENTION

It is therefore an object of the invention to provide a less expensive method for providing a pressure responsive, variable parallel plate capacitive transducer having consistent spacing between its capacitor plates from one transducer to another. Another object is the provision of such a method which has improved the yield. Yet another object is to provide a method for producing such a transducer which has improved reliability and is long lasting.

According to the present invention there is provided a method of fabricating a capacitive pressure transducer having a ceramic diaphragm bonded on to a ceramic base member with two electrodes respectively secured to facing surfaces of the diaphragm and the base member so that the electrodes face one another with a gap between them, the transducer being such that a change of the pressure applied to it causes the gap between the electrodes to change,

wherein the method includes
 taking ceramic powder particles coated with an organic binder and pressing the powder to form the diaphragm and the base member, the base member having a recess formed in its upper surface,
 applying metallised layers to the lower surface of the diaphragm and to the recess in the upper surface of the base member,
 pressing the diaphragm and the base member together with sufficient pressure to cause the diaphragm to adhere to the base member to cover the recess, leaving cells still open in the ceramic material,
 raising the temperature of the diaphragm and base member as a unit to a first temperature to purge the organic binder therefrom through the open cells of the ceramic, and then
 placing the diaphragm and the base member as a unit in a reducing atmosphere and raising its temperature to a second temperature, higher than the first temperature, to sinter the ceramic material thereof so as to produce a monolithic body and to bond the metallised layers to the ceramic.

Briefly, a transducer made by a method according to the invention comprises a body of ceramic material having a cavity formed therein closely adjacent an outer surface thereof. Metal capacitor plates are formed on opposite sides of two surfaces defining the cavity with vias extending to terminal areas. The ceramic comprises conventional material such as 80% by weight alumi-

nia up to essentially 100% with the balance being additives to form a glass at a sintering temperature. The ceramic is provided in powdered form coated with an organic binder, as a spray dried powder, ready for pressing into any selected configuration. First and second portions, i.e., a diaphragm and a base having a recess formed in an outer face surface, are formed by pressing the powder in a die. In one example of the method metallized coatings of high temperatures material such as molybdenum/manganese in the form of a thick film paste, are deposited as by screen printing on one surface of the diaphragm portion and on the recessed outer face surface of the base portion. The vehicle used in the thick paste is then removed, preferably by heating. According to a feature of an example of the invention, a spacer of organic material is placed in the recess to ensure that the cavity gap is maintained during the following pressing step. The two portions are then pressed together to form a single unit and then the unit is heated in an air atmosphere to a first debinderizing temperature. After the organics, including the spacer means, are vaporized/decomposed and released through the still open cells of the ceramic, the unit is placed in a high temperature oven and co-fired in a reducing atmosphere with the metal layers forming a conductive coating bonded to the ceramic and the ceramic being sintered together to form a monolithic, closed cell body.

According to a modified method, low temperature ceramic materials are used for the ceramic which can be sintered at a temperature low enough to permit the use of conventional printed circuit inks fired in an air atmosphere.

According to another modified method, the metallization is printed on the spacer means which is then transferred to the ceramic material during the step of pressing the two portions together.

Brief Description of the Drawings

Other objects, advantages and details of the novel and improved method of making a capacitive pressure transducer appear in the following detailed description of preferred methods according to the invention, the detail description referring to the drawings in which:

Fig. 1 is a blown apart perspective view of a diaphragm, a base and a spacer means prior to being formed in a unitary body;

Fig. 2a is a top plan view of the base with the metallized layer deposited thereon;

Fig. 2b is a bottom plan view of the diaphragm with the metallized layer deposited thereon;

Fig. 3 is a flow chart showing the process steps for fabricating a monolithic sensor in accordance with the invention;

Fig. 4 is a cross section taken through a unit after it has been sintered;

Fig. 5 is a cross section taken through the Fig. 4 unit in a direction chosen to include the vias extending from the capacitor plates; and

Fig. 6 is a cross section, similar to Fig. 4, of a modified transducer.

With particular reference to Figs. 4 and 5 of the drawings, a pressure responsive, variable capacitive transducer made in accordance with the invention comprises a monolithic body of ceramic material having a cavity formed therein closely adjacent an outer surface of the body. Capacitor plates formed of suitable material such as metal, as will be described below, are disposed on opposed surfaces of the cavity with vias extending from the plate to respective terminal pads for connection to externally disposed signal conditioning electrical circuitry (not shown).

Although various ceramic materials can be utilized such as cordierite, mullite, etc., in one example of the method of the invention, a suitable composition comprises between approximately 80% by weight up to essentially 100% alumina with the balance being additives which form a glass at the sintering temperature of the alumina. Such material is conventional in the electronic substrate industry and can be either purchased as a spray dried powder ready to press or can be specifically formulated and spray dried according to known techniques to produce a free-flowing, granulated powder ready for pressing (numeral 1 in Fig. 3). The spray dried powder contains the alumina and an organic binder such as polyvinyl alcohol or other plastic to serve as a temporary adhesive holding the powder together after pressing until the resultant pressed material is sintered.

The alumina spray dried powder is pressed (numeral 2 of Fig. 3) into the shapes of a generally cylindrical diaphragm and a base as shown in Fig. 1 at 20, 22 respectively, using a pressure in the range of approximately 7 to 200 megapascals (1,000-30,000 psi). As seen in the figure a recess or depression 24 of a selected depth of between 25 to 254 micrometres (0.001 to 0.010 inches) is formed in one end face of base 22 at the time it is formed although, if desired, the recess could be formed wholly or partially in the diaphragm as well. The depth of the recess is selected to allow for the shrinkage of the materials, including the capacitor plates, to provide spacing between the electrodes from approximately 13 to 63 micrometres (0.5 to 2.5 mils) in the finished transducer.

After the initial pressing, the diaphragm 20 and base 22 are strong enough to permit handling. A selected electrode pattern is applied (numeral 3 of Fig. 3) to the bottom surface of the diaphragm 20 and top surface of base 22 (Figs. 2a, 2b respectively) by any suitable means, such as screen printing. Any suitable high tem-

perature metal can be used such as tungsten, molybdenum/manganese, platinum or other high temperature material such as a conductive ceramic. For screen printing the metallization is applied in the form of conventional thick film paste which typically contains certain solvents to adjust viscosity for screen printing. After application the solvents can be removed slowly at room temperature or more rapidly by placing the parts into an air oven at approximately 100° C (numeral 4 of Fig. 3).

Although it is possible to press the diaphragm and base together without any spacing means placed therebetween and still maintain a gap between the diaphragm and the bottom of the recessed area, particularly with relatively large gaps, it is preferred to use a fugitive spacer, particularly with relatively smaller gaps. That is, a spacer helps to maintain the separation between the two electrodes and prevent the two electrodes from engaging one another during the next step of pressing the diaphragm to the base. A fugitive spacer element 26 composed of essentially non-compressible, consumable or decomposable material and having a thickness preferably essentially equal to the desired spacing between the electrodes or a plurality of sheets of such material the total thickness of which preferably essentially equals the desired spacing is placed in recess 24 (numeral 5 of Fig. 3). The spacer material is selected so that it is clean burning, i.e., so that there is no ash remaining after the spacer has been thermally removed after pressing the base and diaphragm together. Propylene carbonate and Delrin, a trademark of E.I. du Pont de Nemours Company for acetal, thermoplastic resin, are two such materials, and can be used in various thicknesses depending upon the desired gap. In transducers made in accordance with the invention spacers from 25 to 152 micrometres (0.001 to 0.006 inches) thick have been used. That is, multiple spacers can be employed to accommodate any selected gap dimension.

As seen at 6 in Fig. 3, diaphragm 20 and base 22 are then placed into a die or suitable isostatic press and pressed together using a pressure in a range between approximately 7 to 200 megapascals (1,000 and 30,000 psi).

The diaphragm and base, now pressed together to form a single body or unit is placed in an oven and heated in an air atmosphere at relatively low temperatures, e.g., 300° C in order to evaporate and burn out the binders and spacer material and allow the evaporated matter and combustion gasses to pass through the pores of the body before the body is sintered and the pores closed (numeral 7 of Fig. 3). The temperature is limited by the maximum temperature at which the metallization can be heated in an air or oxygen atmosphere without significant oxidation.

After removing as much as possible of the organic binder and the spacer material during the debinderizing operation, the assembled unit is placed into a high temperature furnace and sintered in the range of approximately 1400 - 1700° C in a reducing atmosphere (nu-

meral 8 of Fig. 3). Typically the atmosphere contains approximately 1 - 100% hydrogen with the balance usually nitrogen or cracked ammonia.

With appropriate binders in the spray dried powder and with an appropriate polymer for the spacing means if one is used, it will be appreciated that the debinderization step could be accomplished as part of the firing cycle.

The specific materials for the metallization and the ceramic are chosen so that the shrinkage rates are close enough to each other to prevent warpage. Further, the thermal contraction of the materials should be sufficiently similar and the temperature profile employed during cooling from the firing temperature such that the cracking does not occur.

Sintering the alumina converts the unit into a monolithic device as shown at 12 in Fig. 4 having a cavity or gap 14 with an atmosphere determined by the sintering atmosphere of the furnace. For vacuum devices the furnace atmosphere could be evacuated prior to reaching the sintering temperature or a suitable hole could be pressed into the base when originally formed. The device could be evacuated after sintering and the hole sealed with suitable sealant material. The sintering step is also used to effect bonding of the metallization layer to the alumina and form a conductive layer.

After the unit has been fired electrical connection means are added as by attaching pins to the metallized vias with conductive epoxy (numeral 9 of Fig. 3) and may be tested as indicated at 10 of Fig. 3. Any suitable notches or the like to provide access to the vias can be provided during the original pressing step. As seen in Fig. 5 the diaphragm may be notched at 40 and 42 to provide access to the terminal pad. The via extending from the diaphragm can be bridged over to a terminal pad on base 22.

In an example of the invention a device was made using 96% by weight alumina. This was pressed into top and bottom cylindrical portions using approximately 35 megapascals (5,000 psi) with a depression of approximately 150 micrometres (0.006 inches) formed in the bottom portion. A metallization layer of molybdenum/manganese thick film paste was applied by screen printing onto one face of the top portion and the recessed face of the bottom portion. The solvents of the thick film paste were removed by placing the parts in an air oven at approximately 100° C. Two sheets of propylene carbonate each having a thickness of 75 micrometres (0.003 inches) were placed in the recess to serve as a spacer and the parts were then placed in a die and pressed together using a pressure of approximately 70 megapascals (10,000 psi). The assembled parts were then heated in air at 0.5°C/min. to 300° C (5 hour soak) to remove the organic binder and spacer material. The unit was then placed into a high temperature oven and sintered at a temperature of 1550°C having an atmosphere of 98% nitrogen and 2% hydrogen. Electrical connection was made to the two metallized layers at vias

extending from the layers and the unit was tested and determined to have a capacitance of approximately 9 picofarads. A layer was cut off the top or diaphragm portion of the unit to make the unit responsive to a selected range of pressures. The unit was then subjected to a series of forces to simulate pressures ranging from 0 to approximately 140 kilopascals (20 psi) at which capacitance values were determined and the device was found to have a reproducible curve.

Fig. 2a shows a typical metallization pattern for base 22 including capacitor plate 26 and via 28 extending to a terminal pad 30 and a guard ring 27. Another metallization pattern is applied to diaphragm 20 including capacitor plate 32, via 34 and terminal pad 36.

The specific thickness of the diaphragm chosen for a selected range of pressures can be obtained by starting with the appropriate thickness required to obtain, after pressing and firing, the thickness desired, e.g., 750 micrometres (30 mils). Alternatively, a standard thickness can be formed and can then be machined after the unit is sintered to the final selected thickness by known grinding techniques. Some type of indexing means can be provided to facilitate this machining step. For example, as seen in Fig. 6, the diaphragm of transducer 12' can be formed having a smaller diameter 44 than the base, or with notched areas to serve as a reference point so that the precise thickness of the diaphragm can be determined. Alternatively, the diaphragm could be doped with known materials to give it a different shade or color than the base.

It will be appreciated that uniform spacing between the capacitor plates or electrodes of a small dimension, i.e., of approximately 63 micrometres (2.5 mils) or less, is necessary in order to obtain satisfactory performance.

Forming the recess by pressing it into one or both of the two components from which the monolithic ceramic body is made allows for precise control of the dimensions of the recess including required parallelism and flatness of the upper and lower surfaces defining the gap. It is known to create larger cavities where such precise dimensional control of the height of the gap as well as parallelism and flatness of the upper and lower surfaces of the gap is not required by using one or more separate annular ceramic layers having a thickness selected to provide the desired depth of the cavity and placing that between other members and then firing to obtain a unitary body useful for example as a strain sensor. This method however would not be suitable for use with a pressed part, having the same shrinkage characteristics as the other components of the device, as thin as that required to obtain the precisely controlled gap which would be needed in a transducer made in accordance with the invention.

It is also within the purview of the invention to employ low temperature ceramics such as alumina, silica or other conventional materials and a glass binder used in making electronic substrates, which can be sintered at temperatures such as approximately 850 - 1000° C

in air along with standard thick film inks for metallization, such as silver palladium, gold, copper and the like. The glass composition is chosen so that densification is complete at that temperature. A significant advantage of using low temperature ceramics is that it avoids having to use a controlled atmosphere during the co-firing process.

It is also according to an example of the invention to print the metallization layers on opposite sides of a spacer element or on one side of separate elements if more than one spacer element is used. The metallized layers will be transferred to the respective surfaces of the diaphragm and base during the pressing operation.

In view of the above it will be seen that a method according to the invention can be less expensive due to the fact that fewer processing steps are required compared to prior art methods. Further, the method needs no grinding operation or at most no more than one grinding operation compared to the need for grinding both sides of the diaphragm and base in the prior art, thereby saving up to 40% or more of the cost. In addition, there is no glass spacer or seal used and therefore no problems with matching the expansion rates of different materials and mechanical properties resulting from any mismatch.

Claims

1. A method of fabricating a capacitive pressure transducer having a ceramic diaphragm (20) bonded on to a ceramic base member (22) with two electrodes respectively secured to facing surfaces of the diaphragm and the base member so that the electrodes face one another with a gap between them, the transducer being such that a change of the pressure applied to it causes the gap between the electrodes to change,

wherein the method includes

taking ceramic powder particles coated with an organic binder and pressing the powder to form the diaphragm and the base member, the base member having a recess formed in its upper surface (1,2),

applying metallised layers to the lower surface of the diaphragm and to the recess in the upper surface of the base member (3,4),

pressing the diaphragm and the base member together with sufficient pressure to cause the diaphragm to adhere to the base member to cover the recess, leaving cells still open in the ceramic material (6),

raising the temperature of the diaphragm and base member as a unit to a first temperature to purge the organic binder therefrom through the open cells of the ceramic (7), and then

placing the diaphragm and the base member

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6. A method according to any one of the preceding claims wherein the first temperature is 300 °C.

7. A method according to any one of the preceding claims wherein the second temperature is in the range 1400 - 1700 °C.

8. A method according to any one of the preceding claims wherein the diaphragm and the base member are pressed together to adhere one to the other at a pressure within the range of 7 to 200 megapascals.

9. A method according to any one of the preceding claims wherein the metallised layers are formed of molybdenum/ manganese, tungsten or platinum.

10. A method according to any one of the preceding claims in which the ceramic powder particles are formed of low firing temperature ceramics.

Patentansprüche

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1. Verfahren zur Herstellung eines kapazitiven Druckwandlers mit einer keramischen Membran (20), die auf einem keramischen Basiselement (22) befestigt ist, wobei zwei Elektroden an gegenüberliegenden

Patentansprüche

55 1. Verfahren zur Herstellung in s kapazitiven Druckwandlers mit einer keramisch n Membran (20), die auf einem keramischen Basiselement (22) befestigt ist, wobei zwei Elektroden an gegenüberliegenden

Ob rflächen d r Membran bzw. des Basisel ments so befestigt sind, daß die El ktroden einander ge- genüberliegen und zwischen den Elektroden ein Zwischenraum ist, und wobei der Wandler so aus- gebild t ist, daß eine auf ihn wirk nde Druckände- rung zu einer Veränderung des Zwischenraums zwischen den Elektroden führt,

bei dem keramische Pulverpartikel genommen werden, die mit einem organischen Bindemittel bedeckt sind, und das Pulver gepreßt wird, um die Mem- bran und das Basiselement zu bilden, wobei in der Oberseite des Basiselements eine Ausneh- mung gebildet ist (1, 2),

Metallisierungsschichten auf der Unterseite der Membran und in der Ausnehmung in der Ober- seite des Basiselements aufgebracht werden (3, 4),

die Membran und das Basiselement mit ausrei- chendem Druck zusammengedrückt werden, so daß die Membran an dem Basiselement haftet, um die Ausnehmung zu bedecken, wobei die Zellen in dem keramischen Material noch offen bleiben (6),

die Temperatur der Membran und des Basis- elements als eine Einheit bis zu einer ersten Temperatur erhöht wird, um daraus das organische Bindemittel durch die offenen Zellen der Keramik zu entfernen (7), und

dann die Membran und das Basiselement als eine Einheit in eine reduzierende Atmosphäre gesetzt wird und die Temperatur bis zu einer zweiten, über der ersten Temperatur liegenden Temperatur erhöht wird, um das keramische Material der Einheit zu sintern, so daß ein monolithischer Körper hergestellt wird, und um die Metallisierungsschichten mit der Keramik zu verbinden (8).

2. Verfahren nach Anspruch 1, bei dem vor dem das Haften der Membran an dem Basiselement bewir- kenden Zusammenpressen der Membran und des Basiselements in die Ausnehmung ein Abstands- element aus organischem Material mit einer Dicke gesetzt wird, die ungefähr der Dicke der Ausneh- mung entspricht (5), wobei das Material des Abstandselements aus der Ausnehmung entfernt wird, wenn die Temperatur auf die erste Temperatur erhöht wird.
3. Verfahren nach Anspruch 2, bei dem die Metallisie- rungsschichten auf den Außenflächen des Abstands- elements gebildet werden und dann von dort auf die Membran und in die Ausnehmung übertra- gen werd n, wenn die Membran und das Basisele- ment zusammengedrückt werden.

4. Verfahren nach Anspruch 2 oder Anspruch 3, bei dem die Dicke des Abstandselements in dem Be- reich von 25 bis 152 Mikrometern liegt.

5. Verfahren nach Anspruch 2, 3 oder 4, bei dem das Abstands element aus Polypropylenkarbonat oder Acetal-Kunstharz hergestellt ist.

6. Verfahren nach einem der vorhergehenden Ansprü- che, bei dem die erste Temperatur 300°C beträgt.

7. Verfahren nach einem der vorhergehenden Ansprü- che, bei dem die zweite Temperatur in dem Bereich von 1400 - 1700°C liegt.

8. Verfahren nach einem der vorhergehenden Ansprü- che, bei dem die Membran und das Basiselement mit einem Druck in dem Bereich von 700 bis 200 Megapascal zusammengedrückt werden, um an- einander zu haften.

9. Verfahren nach einem der vorhergehenden Ansprü- che, bei dem die Metallisierungsschichten aus Mo- lybdän/Mangan, Wolfram oder Platin gebildet wer- den.

10. Verfahren nach einem der vorhergehenden Ansprü- che, bei dem die keramischen Pulverpartikel aus ei- ner Keramik mit niedriger Brenntemperatur gebildet werden.

Revendications

1. Procédé de production d'un transducteur de pres- sion capacitif ayant un diaphragme de matière cé- ramique (20) lié à un élément de base de matière céramique (22) avec deux électrodes respective- ment fixées aux surfaces en regard du diaphragme et de l'élément de base de telle sorte que les élec- trodes soient en regard l'une de l'autre en laissant subsister un intervalle entre elles, le transducteur étant tel qu'une variation de la pression qui lui est appliquée amène le changement de l'intervalle en- tre les électrodes,

dans lequel le procédé comprend les étapes suivantes :

on prend des particules de poudre céramique revêtues d'un liant organique et on presse la poudre pour former le diaphragme et l'élément de base, l'élément de base ayant un évidem- ent formé sur sa surface supérieure (1, 2),
on applique des couches métallisées à la sur- face inférieure du diaphragme et à l'évidement de la surface supérieure de l'élé- ment de base (3, 4),
on presse le diaphragme et l'élément de base

l'un sur l'autr avec une pression suffisante pour amener le diaphragme à adhérer à l'élément de base afin de recouvrir l'évidement, n laissant des cellules encor ouvertes dans la matière céramique (6),
 on relève la température du diaphragme et de l'élément de base dans leur ensemble à une première température pour en purger le liant organique à travers les cellules ouvertes de la matière céramique (7), et
 on place le diaphragme et l'élément de base dans leur ensemble dans une atmosphère réductrice et on relève leur température à une deuxième température, plus élevée que la première température, pour friter la matière céramique de l'ensemble de manière à produire un corps monolithique et à lier les couches métallisées à la matière céramique (8).

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9. Procédé selon l'une quelconque des revendications précédentes, dans lequel les couches métallisées sont formées de molybdène/manganèse, de tungstène ou de platine.

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10. Procédé selon l'une quelconque des revendications précédentes, dans lequel les particules de poudre de matière céramique sont formées de matières céramiques basses températures.

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2. Procédé selon la revendication 1, comprenant l'étape qui consiste à placer dans l'évidement un élément d'espacement d'une matière organique ayant une épaisseur approximativement égale à la profondeur de l'évidement avant de presser le diaphragme et l'élément de base conjointement pour amener le diaphragme à adhérer à l'élément de base (5), la matière de l'élément d'espacement étant purgée de l'évidement lorsque la température est relevée à la première température.
3. Procédé selon la revendication 2, dans lequel les couches métallisées sont formées sur les faces de l'élément d'espacement et sont transférées de celui-ci sur le diaphragme et l'évidement lorsque le diaphragme et l'élément de base sont pressés l'un sur l'autre.
4. Procédé selon la revendication 2 ou 3, dans lequel l'épaisseur de l'élément d'espacement se situe dans la plage de 25 à 152 µm.
5. Procédé selon la revendication 2, 3 ou 4, dans lequel l'élément d'espacement est constitué de carbonate de polypropylène ou de résine acétal.
6. Procédé selon l'une quelconque des revendications précédentes, dans lequel la première température est de 300°C.
7. Procédé selon l'une quelconque des revendications précédentes, dans lequel la seconde température est de l'ordre de 1400 à 1700°C.
8. Procédé selon l'une quelconque des revendications précédentes, dans lequel le diaphragme et l'élément de base sont pressés l'un sur l'autre pour les faire adhérer l'un à l'autre à une pression dans la plage de 7 à 200 mégapascals.

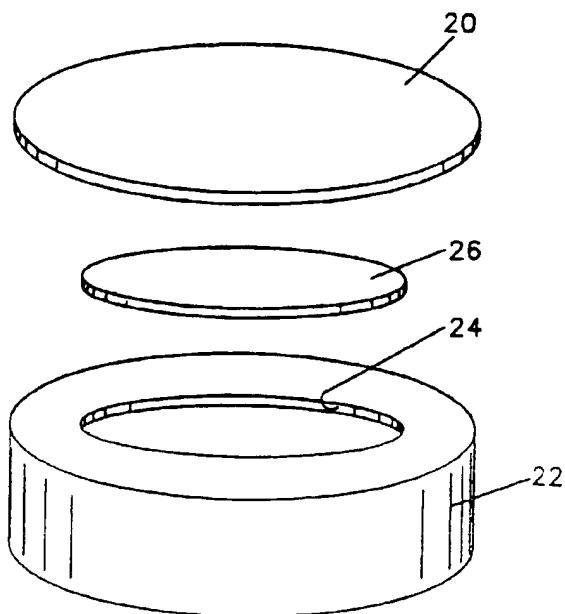


FIG. 1.

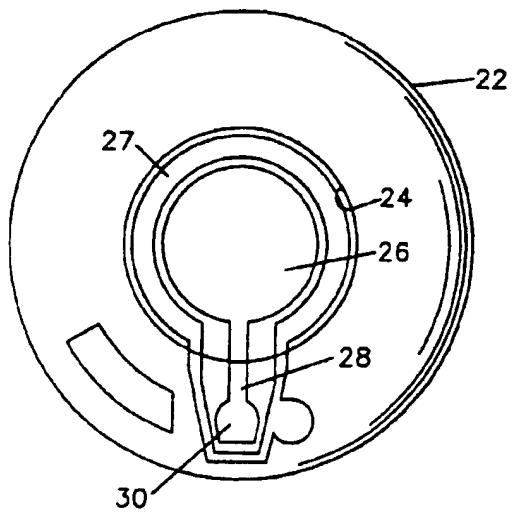


FIG. 2a.

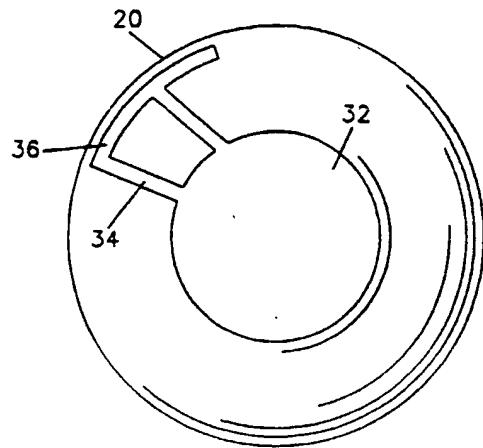


FIG. 2b.

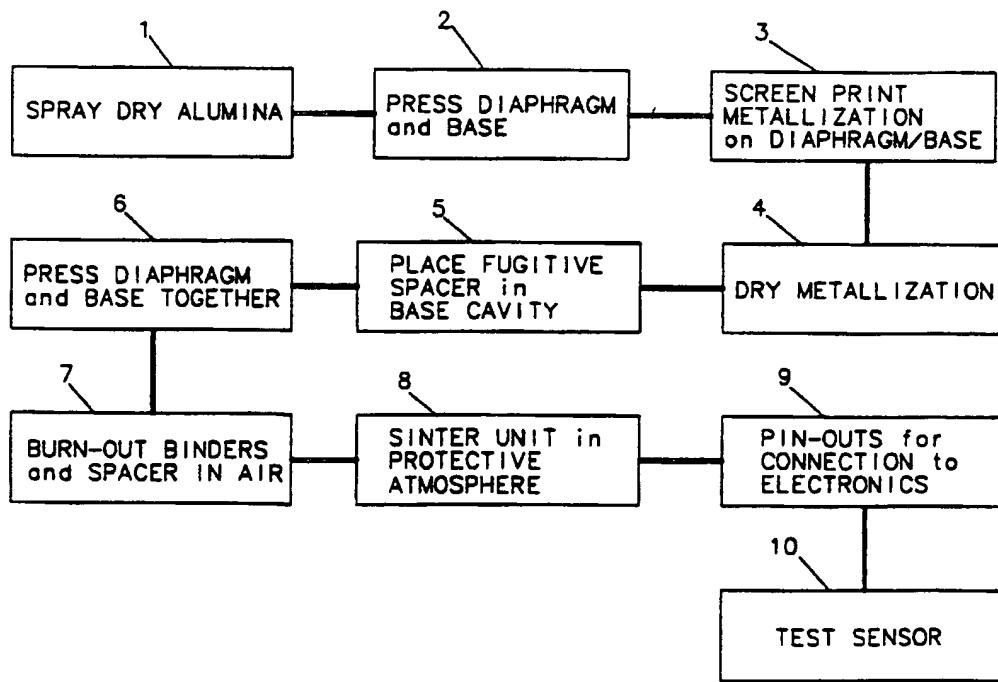


FIG. 3.

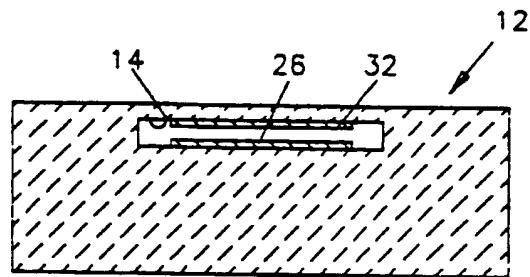


FIG. 4.

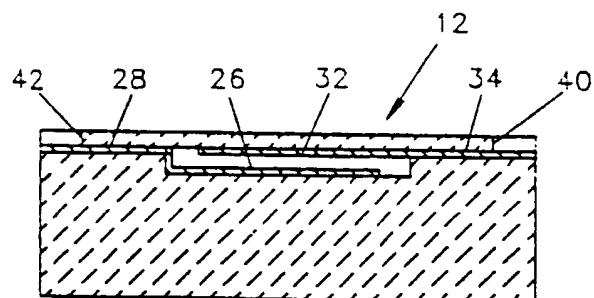


FIG. 5.

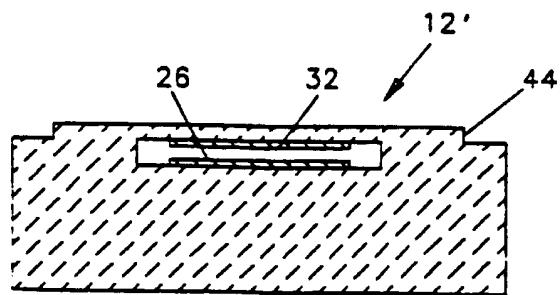


FIG. 6.

